Tech Brief

FEDERAL MOTOR CARRIER SAFETY ADMINISTRATION

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Effects of Sleep Schedules on Commercial Motor Vehicle Driver Performance—Part 1

The goal of the Federal Motor Carrier Safety Administration (FMCSA) is to reduce the number and severity of large truck-involved crashes through more commercial motor vehicle and operator inspections and compliance reviews, stronger enforcement measures against violators, expedited completion of rulemaking proceedings, scientifically sound research, and effective CDL testing, recordkeeping, and sanctions. The Office of Research and Technology manages research and technology development and deployment programs for the FMCSA.

The FMCSA R&T activities encompass a range of issues and disciplines relating to motor carrier safety, including problem assessment; policy, safety management, and outreach; drivers; truck and bus vehicle safety performance; and compliance, enforcement and operations.

Driver alertness and fatigue primarily supports current and future hours-of-service rulemaking activities, along with fatigue outreach and fatigue management technology development.

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Introduction

The Federal Motor Carrier Safety Administration (formerly the Office of Motor Carriers, Federal Highway Administration) sponsored a study to gather and analyze data on commercial motor vehicle (CMV) driver rest and recovery cycles, effects of partial sleep deprivation, and prediction of subsequent performance. The work was carried out in cooperation with the Federal Railroad Administration, and Federal Aviation Administration, by the Walter Reed Army Institute of Research at the General Clinical Research Center/Johns Hopkins Bayview Medical Center. The study began in July 1994 and was completed in May 2000.

Parts 1 and 2 of this tech brief summarize the study final report, *Effects of Sleep Schedules on Commercial Motor Vehicle Driver Performance* (Report DOT-MC-00-133). The report will be available from the National Technical Information Service.

Part 1 of this tech brief describes the study background, purpose, and the methodology and results from the field portion of the study. Part 2 describes the methodology and results from the laboratory portion of the study as well as the overall results, applications, and need for additional research.

Background

Under the current U.S. Federal Hours of Service (HOS) regulations, CMV drivers are restricted to a maximum of 10 hours of driving, and/or 15 hours on-duty time, after 8 consecutive hours off-duty; and a maximum of 60 hours on-duty time over 7 consecutive days—or a maximum of 70 hours over 8 consecutive days for those who operate 7 days per week. However, the HOS regulations do not necessarily prevent significant sleep debt and sleepiness-related performance deficits in CMV operators. This is because: (a) under the regulations driving may occur in the early morning hours; (b) the regulations do not prohibit backward–rotating or highly irregular work/rest schedules; and (c) a minimum off-duty period of 8 hours may not be long enough to ensure adequate sleep, since drivers would also be expected to eat, shower, and take care of other personal needs during this period.

Although it is known that sleep debt impairs performance on a variety of tasks, including driving-related measures, the relationship between hours of sleep and subsequent performance during wakefulness has never been adequately quantified. Relatively few well-controlled studies have investigated the effects of restricted sleep over multiple consecutive days. The lack of such studies is particularly problematic because it is likely that sleep restriction, i.e., inadequate daily sleep, rather than total sleep deprivation (the complete absence of sleep), accounts for most daytime sleepiness in CMV drivers, as well as workers in other occupations.

Purpose

The study was undertaken with four purposes in mind:

- gather data on representative wake-sleep cycles of CMV drivers operating in uncontrolled, naturalistic, settings;
- determine, based upon data collected in a laboratory setting, the effects of schedules involving different amounts of sleep (based upon allowed time-in-bed periods of 3, 5, 7, and 9 hours) on driving task performance, and drivers' physiological and subjective responses;
- extend and validate a numerical model of performance prediction that is based on prior wake-sleep cycles, sleep quality and quantity, and circadian state; and
- install software for this model in a next-generation wrist-worn activity monitor (wrist Actigraph).

Methodology

As previously noted, this project was comprised of a field study and a laboratory study. In the field study—described in this tech brief—wrist actigraphy was used to determine amounts of sleep taken by long- versus short-haul CMV drivers during and outside the work shift. In the laboratory study, described in Part 2 of this tech brief, the effects of different amounts of nightly time in bed on subsequent performance (on psychomotor tasks and simulated driving), were measured. Results were used to optimize the parameters of the Walter Reed Sleep Performance Model. The model, along with a sleep scoring algorithm, has been integrated into the current version of the Sleep Watch Actigraph, a wrist worn device for management of sleep and performance in operational environments.

Field Study: Assessment of the Sleep of CMV Drivers over 20 Consecutive Days

Subjects

Subjects were 50 CMV drivers (men and women), aged 21-65, holding a valid commercial driver's license. Twenty-five drivers, all male, maintained driving schedules which enabled them to return home at the end of most work periods to sleep ("short-haul") drivers. The other 25 drivers, 24 men and 1 woman, maintained schedules that did not always allow them to return home at the end of work periods to sleep ("long haul drivers").

Measures

Wrist actigraphy was used to objectively measure the timing and duration of sleep periods over a 20-day period. Drivers also completed sleep logs to gather subjective information on sleep times, sleep latency, arousals during sleep, alertness upon awakening, napping (number and duration), and self-reported caffeine, alcohol and medication use (see **Figure 1**).

Figure 1.
Sample actigraph records with corresponding Driver's Record of Duty Status (RODS): inconsistency between actigraph and RODS.

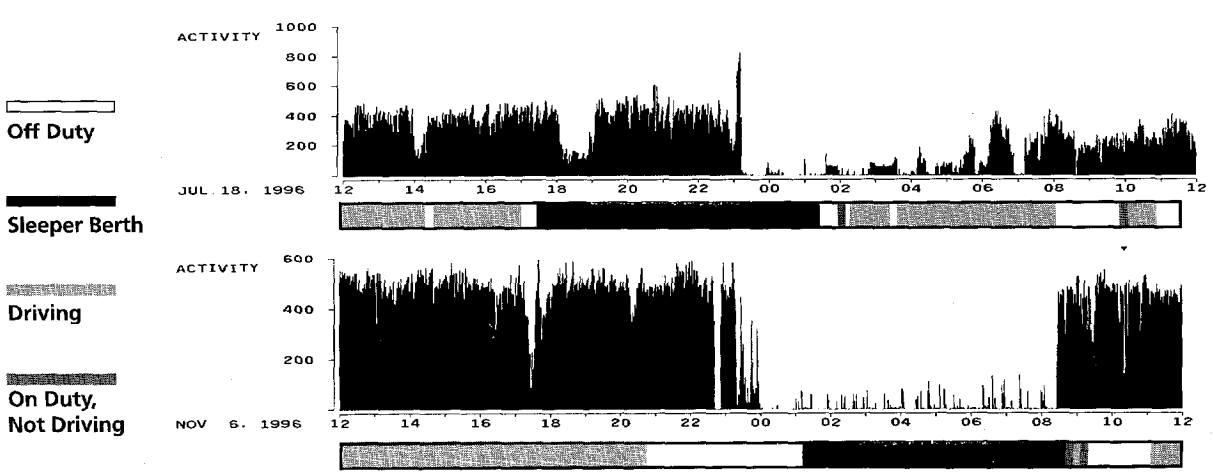


Figure 2.
Frequency distribution of total sleep times per 24-hour period (summed across all possible duty statuses), short-haul drivers.

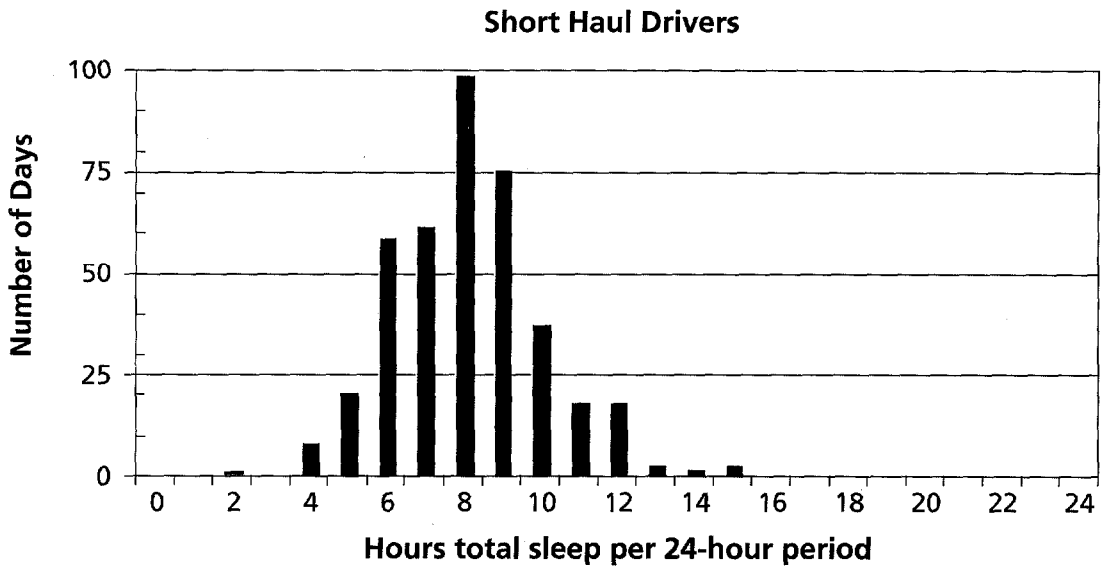
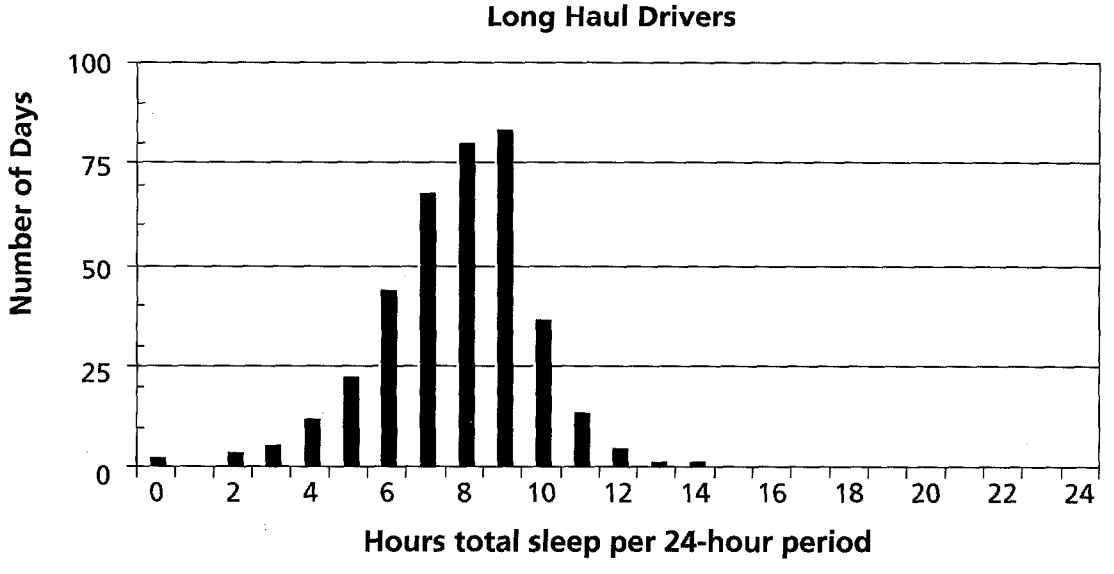


Figure 3.
Frequency distribution of total sleep times per 24-hour period (summed across all possible duty statuses), long-haul drivers.



Data Analysis

Data from each actigraph were downloaded to a personal computer and scored for daily sleep periods by visual inspection of the actigraph records. For each 24-hour period, total sleep within that period was identified and categorized as either: off-duty sleep, i.e., sleep obtained during the primary, or longest off-duty period during the 24-hour day, and sleep taken at other times. Sleep taken at other times included sleep taken during breaks between on-duty periods during the work shift. The amount and timing of daily sleep were calculated for each group of drivers, and the correlations between daily sleep and off-duty time were determined.

Researcher
This study was performed by the Division of Neuropsychiatry, Walter Reed Army Institute of Research, 503 Robert Grant Avenue, Silver Spring, MD 20910; and General Clinical Research Center/Johns Hopkins Bayview Medical Center.
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Distribution
This Tech Brief is being distributed according to a standard distribution. Direct distribution is being made to the Service Centers and Divisions.

Availability
The study final report (DOT-MC-00-133) will be available from the National Technical Information Service, Telephone: (703) 605-6000

Key Words
Sleep restriction, CMV drivers, driving simulator, performance, actigraphy, sleep/ performance model

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Results and Discussion

Both long- and short-haul drivers averaged approximately 7.5 hours of sleep per night, within normal limits for adults. (See **Figures 2** and **3**.) Time off-duty was positively correlated with total sleep time for both groups. The short-haul drivers were more likely to consolidate their daily sleep into a single period. Long-haul drivers obtained almost half of their daily sleep during work-shift hours, mainly sleeper-berth time. This may suggest that they spend a significant portion of the work shift in a state of partial sleep deprivation—i.e., until the opportunity to obtain recovery sleep presents itself.

There was no off-duty duration for either group that guaranteed adequate sleep. For example, one driver obtained no sleep during a 20-hour off-duty period. Likewise, large day-to-day variations in total sleep time were evident for drivers in both groups, with some individuals showing a pattern suggesting chronic sleep restriction with intermittent bouts of extended recovery sleep. The findings suggest that, although work/rest schedules can be devised to help minimize commercial driver sleep debt, optimal enhancement of driver alertness and performance will require additional approaches.

Reference
Balkin, T., Thome, D., Sing, H., Thomas, M., Redmond, D., Wesensten, N., Williams, J., Hall S., Belenky, G. *Effects of Sleep Schedules on Commercial Motor Vehicle Driver Performance.* FMCSA Report No. DOT-MC-00-133, May 2000.